"Limits of Nb_3Sn" Working Group

Preliminary report

43rd INFN Eloisatron Workshop

Super Magnets for Supercolliders

Erice, October 26 – November 1, 2003

Proposed work plan

- Concentrate on very high field magnets

(LHC upgrade is the most likely application in the "near" term)

Discussion Topics:

- Coil Design
- Mechanical support & assembly
- conductor, operating temperature ⇔ conductor/materials w.g.
- aperture, field quality, dyn. range ⇔ *accelerator physics w.g.*
- stored energy, inductance ⇔ quench protection w.g.
- radiation issues ⇔ ancillary systems w.g.
- *magnet cost* ⇔ *all of the above*

- Establish R&D targets? (as for DOE conductor program)

Coil Design

- Concentrate on cosθ and block for very high field
- Main differences are cable and stress distribution
- Cable: need more work on keystoned cables
  - assess mechanical and degradation limits
  - special cores to increase keystone limits
- Stress distribution vs. field
  - after discussion, agreement on basics stress characteristics
  - perform more detailed comparisons (stress maps)
- Also consider efficiency and cost factors
  - complexity (design, parts and assembly)
  - flexibility, in particular for R&D
- Keep exploring new ideas (comb. function, warm iron etc.)

Mechanical Support

- Several mechanical support concepts are being explored:
  - collars; Al clamps
  - bladders (no keys); bladders (with keys)
  - rods/bolts, wire wraps
- There are issues that need to be addressed for each concept
  - Bladders: long magnets, position & alignment accuracy
  - Collars: springback, total stress delivered
  - …..
- Very robust performance has been demonstrated for Nb_3Sn
- Some of the developments can be beneficial to NbTi as well

Stress limits

- RD3b, HD-1 show limits are higher than previously thought
- However, no clear boundaries have been established
- Dedicated experiments are necessary
- Sub-scale tests are attractive but feasibility is not obvious
- Small coil tests in full scale structure are one possibility
- Insert coil tests in full scale magnets are another possibility
- Correlation needed between strand and magnet performance
- Stress criteria for strands may then be established

Quench performance & training

- Magnet quench performance & training needs to be improved
- Fundamental performance and cost issue, esp. at high field
- Different viewpoints on mechanisms causing premature quenches
- Different viewpoints on best R&D strategy & tools
- Systematic analysis of quench mechanisms is needed
  - Theory: 3D modeling available
  - Experiments: special instrumentation can be developed
- Examples of effects to be investigated:
  - Effect of face side shear, high preload & bond vs low preload and let slip
  - Quench mechanism in ends, methods of preload
  - Issues with ramps, transitions and joints

Conductor (1)

- A lower copper fraction may be feasible for RRP wires
  - Ic increase by +20% gives +0.5 T in HD-1 at 4.2 K
  - Well worth pursuing! some risk (drawing, cabling)
- Focus on 15T+ J_c improvements (change J_c criterion to 15T)
- Low magnetization is not a priority for near term magnet development
- However, better stability is a priority (both flux jump and MQE)
- A D_{eff} goal of $\leq 50\ \mu m$ appears to be satisfactory for the near term
  - keep pushing on Ic, high field Jc and stress tolerance instead
  - A statement from AP is required regarding LHC luminosity upgrade specs
- Much smaller filaments may be ultimately needed - develop in parallel?

Conductor (2)

- Ic measurements at 1.9 K in 16-20 T range are needed
- Further R&D on keystoned cables required for cosθ designs
  - Some work already planned in connection with LARP
- Pay close attention to new conductors (e.g. with SM "technology" tests)

Proposed Magnet R&D Targets

- Technology:

  #1: Bore field ≥ 18 T with ≥ 5 mm clear bore
  #2: Bore field ≥ 16 T with ≥ 30 mm clear bore (cold bore included)
  #3: Bore field ≥ 14 T with ≥ 3 m magnetic length

- Dipoles (B_0^{nom}=14 T, harmonics as measured at 10 mm physical radius):

  #4: All central harmonics ≤ 3 units at B_0^{nom}
  #5: All central harmonics ≤ 10 units from 0.1*B_0^{nom} to B_0^{nom} @ LHC R.R.

- Quadrupoles (G^{nom}=200 T/m, harm. as measured at 20 mm physical radius)

  #6: All central harmonics ≤ 3 units at G^{nom}

Summary

- 16 Tesla achieved, and there is still a lot of potential
- More R&D needed to select best coil configuration for each application
- Several concepts for mechanical support are being developed
- Robust mechanical behaviour demonstrated for Nb_3Sn magnets
- Systematic experimental analysis of stress limits is needed
- Systematic theoretical/experimental analysis of quench/training is needed
- More high field Jeff is still the highest priority for conductor development
- Proposing magnet R&D targets to help focus and measure progress